FORESTRY 168

Wood Properties of Subalpine Fir, A British Columbia Interior Wood

ISSN 0835-0752

SEPTEMBER 1991

Canada

BC

Wood Properties of Subalpine Fir, A British Columbia Interior Wood

by

L.A. Jozsa

Forintek Canada Corporation
2665 East Mall
Vancouver, B.C.
V6T 1W5

prepared for

B.C. Ministry of Forests
Research Branch
31 Bastion Square
Victoria, B.C.
V8W 3E7

September 1991

CANADA-BRITISH COLUMBIA PARTNERSHIP AGREEMENT ON FOREST RESOURCE DEVELOPMENT: FRDA II

Canada

BC

92-05277/

Funding for this publication was provided by the Canada-British Columbia Partnership Agreement on Forest Resource Development: FRDA II – a four year (1991-95) $200 million program cost-shared equally by the federal and provincial governments.

Canadian Cataloguing in Publication Data

Jozsa, L. A.
Wood properties of subalpine fir, a British Columbia interior wood

(FRDA report, ISSN 0835-0752 ; 168)

Issued under Canada-British Columbia Partnership Agreement on Forest Resource Development: FRDA II.
Co-published by B.C. Ministry of Forests.
Bibliography: p.
ISBN 0-7726-1431-8

1. Abies lasiocarpa. 2. Conifers - British Columbia. I. Canada. Forestry Canada. II. British Columbia. Ministry of Forests. III. Canada-British Columbia Partnership Agreement on Forest Resource Development: FRDA II. IV. Title. V. Series

SD397.F5J69 1991 634.97548 C91-092325-6

© 1991 Government of Canada,
Province of British Columbia

This is a joint publication of Forestry Canada and the British Columbia Ministry of Forests.

For additional copies and/or further information about the Canada-British Columbia Partnership Agreement on Forest Resource Development: FRDA II, contact:

Forestry Canada
Pacific Forestry Centre
506 West Burnside Road
Victoria, B.C. V8Z 1M5
(604) 363-0600

or

B.C. Ministry of Forests
Forest Science Research Branch
31 Bastion Square
Victoria, B.C. V8W 3E7
(604) 387-6719

ACKNOWLEDGEMENTS

The author is grateful for the financial support received for this project from the Canada-British Columbia Forest Resource Development Agreement. I am indebted to the many experts who gave me first-hand impressions about subalpine fir in British Columbia and Alberta. Their observations and perceptions helped me in formulating the current picture and the future potential for the species.

I am grateful to a number of colleagues who have read the manuscript and offered valuable comments: Frank Barber, George Coombs, Les Herring, Robert Kellogg, Gerry Middleton, Luiz Oliveira, Cindy Pearce, Brett Salmon, Dick Smith, Chris Stieda, Craig Sutherland, and Rod Willis. I am especially grateful to Ingrid Davis and Roberta Parish for their expert editing of the final draft.

SUMMARY

The wood properties of subalpine fir (*Abies lasiocarpa* (Hook) Nutt.) were compared with those of interior spruce (*Picea* spp.) and lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.), subalpine fir's principal associates in British Columbia. Current manufacturing uses and future potential for subalpine fir were also considered. Information was gathered from the literature and from discussions with the experts who grow, log, mill, pulp, and use subalpine fir.

On the basis of standing timber volume estimates, subalpine fir is a major tree species in the interior of British Columbia. It has a poor reputation, however, because much of the wood being used is decadent and comes from over-mature forests. The main problems with subalpine fir are: a high incidence of decay in the trees, which reduces lumber and chip recovery; difficulties with lumber drying, which results in lumber degrade; and an inherently low density wood that leads to weak dimensional lumber and plywood and low kraft pulp yields. For the next 20 years, the solid wood products market for subalpine fir is expected to remain unchanged, unless it undergoes revitalization similar to that which has occurred for lodgepole pine. So far, subalpine fir has found the greatest acceptance in the pulp and paper sector, where the future looks bright in the prospects for growth in the world market.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS iii

SUMMARY iv

1 INTRODUCTION 1

2 THE RESOURCE 1

2.1 Distribution 1
2.2 Standing Volume 1
2.3 Growth 3
2.4 Decay and Insects 4

3 THE RAW MATERIAL 5

3.1 Gross and Microscopic Features of The Wood 5
3.2 Mechanical and Physical Properties of The Wood 5
3.3 Gross and Microscopic Features of the Bark 6

4 CURRENT MANUFACTURING USES OF SUBALPINE FIR 6

4.1 Lumber 6
4.1.1 Drying 6
4.1.2 Grading 7
4.2 Truss Manufacturing 7
4.3 Pulp Processing 8
4.4 Other Manufacturers 8
4.5 Summary of Principal Properties and End Uses of S-P-F 8

5 FUTURE POTENTIAL 9

6 INFORMATION NEEDS ON WOOD QUALITY 10

7 CONCLUSIONS 10

8 REFERENCES 11

TABLES

1 Interior British Columbia mature standing timber volumes and log production in 1987 3

2 Decay percentage reduction factors in use for volume computation of 30 cm DBH standing living trees 4

3 Average fibre dimensions 5

4 Principal mechanical properties of small clear wood samples, in green condition 5

5 Green wood requirements (m^3) to produce 1 metric tonne of air-dry pulp 8

6 Principal properties and end uses of S–P–F 9

FIGURES

1 Distribution range of true firs in Canada and subalpine fir's principal associates in British Columbia 2

2 Forest regions and percent mature standing volumes of subalpine fir in British Columbia 3

1 INTRODUCTION

In British Columbia, subalpine fir (*Abies lasiocarpa* (Hook) Nutt.) has developed a poor reputation in the wood products industry because of its low wood density, high moisture content, and high incidence of decay. When compared to those of other softwood species, these wood properties result in weak dimensional lumber and plywood, low kraft pulping yields, kilning difficulty, and poor lumber and chip recovery.

This poor reputation aside, subalpine fir accounts for 22% of the total mature standing softwood volume in the interior of British Columbia and, as logging operations move to higher elevations, it will constitute an increasing proportion of the provincial timber harvest. To understand this species better, we carried out a review to compare the wood properties of subalpine fir with its principal tree species associates: lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.), Engelmann spruce (*Picea engelmannii* Parry), and white spruce (*Picea glauca* (Moench) Voss).

This review is based on a literature search and personal communications with British Columbia experts working with subalpine fir, including foresters, sawmill quality control supervisors, truss fabricators, wood preservation specialists, and researchers in the pulp and paper sector. Their observations and perceptions, along with the information in the literature, have helped us formulate the current picture and future potential of subalpine fir.

2 THE RESOURCE

2.1 Distribution

Of about 40 species of true firs worldwide, 9 grow in North America. Of these, four grow in Canada. The distribution of these four species is shown in Figure 1. Balsam fir (*Abies balsamea* (L.) Mill.) has the widest distribution across Canada; amabilis fir (*A. amabilis* (Dougl.) Forbes) is confined to the coastal region of British Columbia, with the exception of the Queen Charlotte Islands; and grand fir (*A. grandis* (Dougl.) Lindl.) is restricted to low elevations in the southern parts of the Coast and Columbia Forest Regions. Subalpine fir has the widest range in British Columbia. It can be found at the higher elevations (610–2440 m) and, except for grand fir in south-central British Columbia, it is the only true fir species found in the British Columbia Interior.

The distribution of the principal associates of subalpine fir is also shown in Figure 1. Both lodgepole pine and white spruce have ranges similar to it in British Columbia. Engelmann spruce habitat is restricted to the southern half of British Columbia's Interior, and overlaps with the range of white spruce. Hybrids are commonly found among the two spruces where their ranges overlap. Some experts refer to these two spruces as "interior spruce" because their wood properties are very similar (Hosie 1969).

2.2 Standing Volume

Subalpine fir makes up a major portion of the mature timber in British Columbia. Standing timber volumes were estimated at about 1133 million m^3 in 1987 (COFI 1988). Accounting for 22% of the total softwood volume (Table 1), it is a close third behind interior spruce (31%) and lodgepole pine (27%). These numbers include stands which may not be economically accessible, however.

The proportion of subalpine fir standing volumes within the Forest Regions in British Columbia is shown in Figure 2. About 80% is found in the Prince George and Prince Rupert Forest Regions.

Although subalpine fir is being undercut, given its inventory (Table 1), the trend is towards increased harvests. Twenty years ago, subalpine fir made up only 5.8% of the cut in the Interior (Dobie 1970). By 1987 it had doubled to 11% of log production. This still lagged behind lodgepole pine (37%) and spruce (33%) (COFI 1988), and is much less than its representation in the mature timber profile (22%).

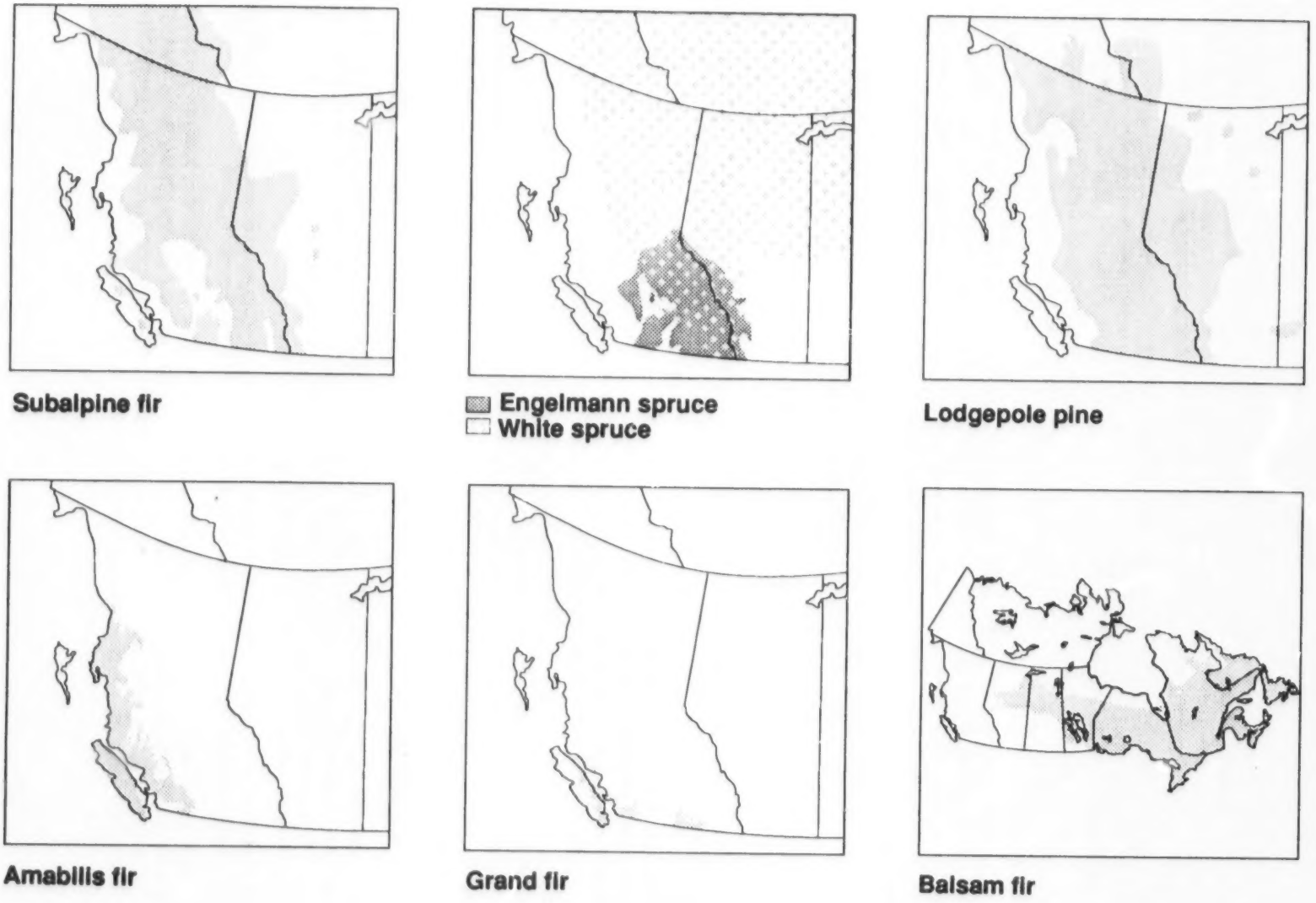

FIGURE 1. Distribution range of true firs in Canada and subalpine fir's principal associates in British Columbia.

TABLE 1. Interior British Columbia mature standing timber volumes (million cubic metres) and log production (thousand cubic metres) in 1987 (COFI 1988)

Species	Standing timber		Log production	
	MM m^3	%	M m^3	%
Spruce	1 635	31	18 010	33
Lodgepole pine	1 396	27	21 249	37
True firs[a]	1 133	22	6 292	11
Hemlock	584	11	3 259	6
Douglas-fir	261	5	4 698	8
Redcedar	173	3	1 837	3
Others	60	1	1 058	2
Total softwood	5 242	100	56 403	100

[a] Includes minor volumes of grand fir from the south-central Interior.

FIGURE 2. Forest regions and percent mature standing volumes of subalpine fir in British Columbia.

2.3 Growth

Eis and Craigdallie (1983), in a study of older trees, examined 132 pairs of white spruce and subalpine fir growing adjacent to each other throughout the interior of British Columbia (from 52–56° north latitude, and 121–126° west longitude).[1] The trees ranged from 50 to 215 years in age, 20 to 60 cm in DBH, and 10 to 40 m in height. The authors reported that the volume of individual subalpine fir trees was greater than that of spruce

[1] This represents the nothern half of the Cariboo Region and the southern half of the Prince George Region.

up to the age of about 100, the difference being greatest at about age 80. The reason was better height and diameter growth in subalpine fir during the immature phase. At about age 80, however, subalpine fir growth started to decline rapidly, while spruce kept growing at a higher rate and eventually produced larger trees.

Smaller piece size of subalpine fir, relative to spruce, is a characteristic of British Columbia's overmature high elevation stands. This has increased the costs of harvesting and processing, resulted in a lesser quantity and quality of lumber (Monchak 1982), and hurt subalpine fir's reputation amongst foresters as a crop species.

2.4 Decay and Insects

Wood-rotting fungi are responsible for most of the volume loss in our mature standing timber resource in British Columbia. Decay loss factors for subalpine fir, interior spruce, and lodgepole pine are shown in Table 2 (B.C. Forest Service 1976). This comparison and the work of others show that the natural decay resistance of subalpine fir wood is low (Bier *et al.* 1948; Fowells 1965; Smith and Craig 1968, 1970; Isenberg 1980).

TABLE 2. Decay percentage reduction factors in use for volume computation of 30 cm DBH standing living trees (B.C.Forest Service 1976)

	Decay reduction (%)		
	Subalpine fir	Interior spruce	Lodgepole pine
Living trees with no indicators of decay	17.4	3.8	8.1
Living trees with pathological indicators (broken or dead tops, mistletoe, etc.) but no conks	23.4	8.2	10.8
Living trees with conks	38.3	24.2	40.3

Presently, much of subalpine fir's poor reputation is related to decay. A high proportion of decay in logs results in higher processing costs. During harvest, much of the subalpine fir ends up in landing cull piles. In manufacturing, poor log quality results in poor lumber and chip recovery, and difficulty in peeling veneer. In living subalpine fir, Bier *et al.* (1948) found that 87% of the decay is caused by two wood-destroying fungi, *Echinodontium tinctorium* (Ell. & Ev.), also known as the Indian paint fungus, and, *Stereum sanguinolentum* (Alb. & Schw. ex Fr.), or bleeding conk fungus. Other studies, notably, Smith and Craig (1968, 1970), also indicate that the highest wood decay losses can be attributed to these two fungi.

Although high wood volume losses are caused by these two fungi, several studies indicate that decay is age dependent. Bier *et al.* (1948) reported that decay was present, but not serious, for subalpine fir trees less than 80 years of age. They reported that the pathological rotation (as indicated by the period of maximum net periodic increment) occurred from 121 to 140 years of age for subalpine fir.

Similarly, Smith and Craig (1968) reported decay to be of little importance in trees less than 80 years of age, but especially serious in those over 160. If Herring (1977) is correct in assuming that rotation length will seldom exceed 140 years in second growth subalpine fir stands, then the incidence of decay should be minimal in the future.

Although decay accounts for the greatest loss in wood volume, subalpine fir is also attacked by several species of insects, one being the balsam woolly aphid (*Chermes piceae* Ratz.). Aphid infestation causes subalpine fir trees to produce annual rings with abnormally large amounts of dark, reddish wood. The number of traumatic resin canals increases in infested wood, as does relative density, and fibre length is about 40% shorter than normal. Aphid-infested trees with such wood produce boards that tend to warp and split. Infested trees also yield pulp that is inferior to that from normal wood (Doerksen and Mitchell 1965).

3 THE RAW MATERIAL

3.1 Gross and Microscopic Features of the Wood

The wood of subalpine fir is whitish to light buff and yellowish brown. Sapwood and heartwood are indistinguishable. The wood is light, moderately soft, generally straight and even-grained, and without characteristic taste or odour if dry (wetted wood has a distinct rank odour). In cross section, rays are fine and indistinct without magnification. Earlywood occupies at least one-half to two-thirds of the annual ring, and the transition to latewood is gradual. The latewood is visually distinct, and variable in colour and relative density. Average fibre dimensions are shown in Table 3 for subalpine fir, Engelmann spruce, and lodgepole pine.

TABLE 3. Average fibre dimensions (Isenberg 1980)

	Fibre length (mm)	Fibre diameter (μm)	Average cell wall thickness (μm)
Subalpine fir	3.0	29	2.0
Engelmann spruce	3.0	25–30	2.9
Lodgepole pine	3.1	35–45	3.0

Because fibre length, fibre diameter, and cell wall thickness all have a direct bearing on the strength qualities of paper, these three Interior species should provide paper fibres of comparable strength, given their similar fibre dimensions. For the same reasons, wood products from these species should have similar texture and grain. However, the smaller average cell wall thickness of subalpine fir wood results in lower relative density.

3.2 Mechanical and Physical Properties of the Wood

The mechanical, or engineering characteristics of wood describe its strength potential. *Modulus of rupture* (MOR) is a measure of how much load a joist or rafter will carry in bending. It is determined by a bending test to failure, usually carried out with the test piece supported on its narrow edge. *Modulus of elasticity* (MOE) is a measure of the resistance to bending, and is directly related to the stiffness of a board or beam. This is a non-destructive test that is routinely carried out at high speeds on machine stress rating (MSR) equipment (Logan and Bechtel 1983).

A known relationship between MOR and MOE, and on-going quality control testing for MOE and minimum MOR, assure the quality of the final product. The MOE is also a factor in the strength of long columns. *Compression parallel to grain* is a measure of the load that can be put on a column in the direction of the grain before the fibres are crushed. *Compression perpendicular to grain* is a measure of the load that compresses the fibres on their sides (side-grain crushing). *Shear parallel to grain* is a measure of the shearing load that can be applied along the grain before the fibres separate and slide in the fibre direction.

Table 4 lists these principal mechanical properties for subalpine fir, Engelmann spruce, and lodgepole pine.

TABLE 4. Principal mechanical properties of small clear wood samples, in green condition (Jessome 1977)

Name	Basic relative density	Static bending		Compression		Shear parallel to grain (MPa)
		MOR (MPa)	MOE (MPa)	Parallel (MPa)	Perpendicular (MPa)	
Subalpine fir	0.33	35.6	8690	17.2	1.79	4.74
Engelmann spruce	0.38	39.0	8620	19.7	1.90	4.99
Lodgepole pine	0.40	39.0	8760	19.4	1.85	4.84

For dimensional lumber, relative density is an all-encompassing indicator of potential wood quality and strength (Jessome 1977; Haygreen and Bowyer 1989). When using relative density as a wood quality indicator, however, one should remember that all other variables must be equal. Some of these variables are piece size, grain angle, moisture content, and size and frequency of knots.

The strength values cited in Table 4 appear to rise with increasing relative density, but not all mechanical properties are affected to the same degree by changes in relative density.

According to small, clear MOE test results, subalpine fir is comparable in stiffness to Engelmann spruce and lodgepole pine (MOE 8690 compared to 8620 and 8760, respectively). However, its MOR value of 35.6 is about 9% less than that of Engelmann spruce and lodgepole pine. Even though these three species have very similar stiffness ratings (MOE), subalpine fir cannot carry the same load in bending as the other two. That species is therefore a bit of an anomaly in this respect, and it is a weaker wood than Engelmann spruce and lodgepole pine.

One should note that the above strength data represent ultimate strengths obtained from testing small, clear specimens (about 5x5 cm square), and are used here for comparative purposes only. Building codes and design specifications use in-grade strength data obtained from the tests of the lumber of commercially available species and sizes (i.e., full size lumber pieces) (Madsen and Sexsmith 1983). Unfortunately, such data are not available at present for subalpine fir.

3.3 Gross and Microscopic Features of the Bark

On average, a stem of subalpine fir, Engelmann spruce, and lodgepole pine contains about 13.5, 10.1, and 13.0% bark by volume, respectively. Double bark thickness values for the three species are reported to be 11.9, 14.2, and 9.2 mm, respectively (Nielson *et al.* 1985).

The inner bark of subalpine fir contains sclereids, or stone cells (cells that are analogous to the gritty particles found in pears). Since sclereids will not accept certain dyes or coatings, their presence results in small white spots in colour-printed papers, or carbonless spots in carbon papers (Forster 1987; Haygreen and Bowyer 1989).

Inner-bark particles get into the pulp mill furnish from incompletely barked saw or pulp logs, particularly when frozen logs are being debarked. In fresh logs, the colour of the inner bark is very similar to that of the wood, and the debarker operator can overestimate bark removal efficiency. Mills using sawmill residual chips from slabs are therefore particularly susceptible to sclereid problems. Obviously, complete bark removal alleviates the problem. Centrifugal cleaners are used in pulp mills to filter out these unwanted particles (Forster 1987).

Although stone cells are found in most species of wood, interior spruce and lodgepole pine are not among the problem species. In western Canada, the highest reported levels are found in *Abies* and *Tsuga* species.

4 CURRENT MANUFACTURING USES OF SUBALPINE FIR

4.1 Lumber

4.1.1 Drying

Moisture content is a highly variable wood property, differing between regions, mills, and trees, and within the trees themselves. For example, average green moisture contents published for subalpine fir, Engelmann spruce, and lodgepole pine are 65, 64, and 50%, respectively, based on the oven-dry weight (Nielson *et al.* 1985). However, Salamon (1975) found that the average green moisture contents of five different shipments of subalpine fir ranged from 73 to 92%, and in the individual pieces, from 30 to 180%. In addition to their highly variable moisture contents, subalpine fir trees frequently contain some wet-wood pockets that are difficult to dry to a consistent moisture content.

The importance of developing suitable schedules for drying subalpine fir has increased in recent years because larger amounts of subalpine fir are being cut in some areas. When subalpine fir is dried with Engelmann spruce and lodgepole pine to desired target levels (below 19% moisture content), the spruce and pine can become overdried. Overdrying results in high levels of drying degrade, such as warp, checks, and splits.

Conversely, if the drying schedule is set for the spruce (S) and pine (P), some of the fir (F) component boards will remain too wet, falling short of the National Lumber Grades Authority standards (95% of the pieces have to be below 19% moisture content to minimize fungal degrade). If a kiln charge of green lumber, composed of equal proportions of S–P–F were examined, some excessively wet boards of lodgepole pine and Engelmann spruce would also be found, although not as many as of subalpine fir. Thus, selecting and sorting out subalpine fir boards may not solve the drying problem. Sorting on the basis of excessive wetness, rather than of species, would seem more practical, as long as drying rates for S–P–F species are similar.

Two technologies are in place today to sort according to moisture classes: one is Forintek's moisture sensor (Troughton and Clarke 1987); the other is a weighing method that identifies particularly heavy, wet pieces.

Once the wet pieces are segregated, there are two options for drying. The first is to dry the wood under the appropriate kiln schedule; the second is to air-dry the wood prior to kiln-drying. Three to four weeks of air-drying can reduce a 96-hour drying schedule to 48 hours. This method can be beneficial in equalizing the moisture differences, even if wet lumber cannot be sorted from the S–P–F mix. However, the drawbacks to air-drying are the large inventory of wood that is present at all times, putting a heavy demand on space requirements in the mill yard, and the additional record keeping required to ensure smooth material flow (Mackay and Oliveira 1989).

4.1.2 Grading

Subalpine fir lumber is classified as either structural or non-structural. The latter is visually graded on the basis of appearance; structural grade lumber can be machine stress rated. Machine stress rating (MSR) may enable producers of dimensional lumber to obtain more value for the higher density pieces within the subalpine fir component. Presently, MSR lumber commands a premium of about 12% over visually graded lumber.

The question is often asked, "How much subalpine fir lumber can be put in the S–P–F mix"? According to the standard grading rules for Canadian lumber, set by the National Lumber Grades Authority, "lumber marked with a combination grade stamp may be all of any one species or some mixture of any of the species in the combination" Pure subalpine fir shipments are not sought, but subalpine fir lumber is accepted in the marketplace as part of the S–P–F group. If subalpine fir is separated for processing, it is usually remixed into the S–P–F mix before shipment. This extra handling means higher costs.

4.2 Truss Manufacturing

The S–P–F mix is used in both visual and MSR grades in truss fabrication. Truss manufacturers have no difficulties with the use of subalpine fir, especially with MSR-graded lumber, because machine stress rating "guarantees" assigned strength classes (Logan and Bechtel 1983).

In general, truss manufacturers are concerned about the holding ability of metal connector plates when they use lower density wood. Although grading rules allow wane, the manufacturers prefer "lumber with four corners." Every millimetre of the wide face is required to transfer the stresses through the connector plates from one truss member to another.

Within the S–P–F mix, truss manufacturers consider lodgepole pine as their first choice because of its small knots, although interior spruce and subalpine fir are close seconds. The S–P–F species group finds its greatest utility in trusses as web members and in lighter structures.

4.3 Pulp Processing

In pulping studies, subalpine fir has performed well when compared to its two companion species. Good quality bleached groundwood and kraft pulps and sulfite viscose-grade pulps can generally be produced readily from Engelmann spruce, subalpine fir, and lodgepole pine (Hyttinen *et al.* 1958). In one study, unbleached subalpine fir pulps showed good strength properties and could be substituted for spruce, except in cases where brightness was critical (Simmonds 1965).

However, between the three species, differing amounts of green wood are required to produce 1 metric tonne of pulp (air-dried at 10% moisture content). Approximately 1 m^3 (20%) extra subalpine fir wood is required to produce the same 1 tonne of kraft pulp as the other two species (Table 5). The main reasons are the differences in relative density and, to some degree, the difference in lignin content. Pulp mills prefer to use subalpine fir chips blended into the furnish at about a 10–20% rate, even when they have a segregated 100% subalpine fir chip pile, because a larger amount of subalpine fir chips is required to produce a given tonne of pulp.

TABLE 5. Green wood requirements (m^3) to produce 1 metric tonne of air-dry pulp (Nielson *et al.* 1985)

Species name	Kraft unbleached (m^3/tonne)	Kraft bleached (m^3/tonne)	Mechanical pulp (m^3/tonne)	Relative density
Subalpine fir	6.22	6.62	2.88	0.33
Engelmann spruce	5.21	5.56	2.63	0.38
Lodgepole pine	5.00	5.32	2.32	0.40

4.4 Other Manufacturers

Plywood manufacturers use subalpine fir exclusively as inner plies. Plywood mills could use more subalpine fir if it were not for the poor log quality of big peelers, which are prone to ring shake and pocket rot.

The manufacturers of glue-laminated timber beams do not use subalpine fir, because the codes and standards do not permit it (CSA 1984).

4.5 Summary of Principal Properties and End Uses of S–P–F

Table 6 lists 15 principal properties and the most common uses of subalpine fir, Engelmann spruce, and lodgepole pine wood.

It is interesting to note that of the 15 properties, 11 are identical or not significantly different. The four properties of subalpine fir that are inferior to Engelmann spruce and lodgepole pine are relative density, heating value, beam strength, and nail withdrawal resistance. Relative density and beam strength have been discussed above. Nail withdrawal resistance has not been reported as a problem; if it were, spiral nails could be used in specialized applications.

Note that the number of uses listed for each species reflects the species' overall quality and its acceptance in the marketplace. New developments in forest products research and process technology may alter some of the rankings shown in the table. For example, a recent comparison of treatability of material showed that, in every case, incised subalpine fir was more treatable than incised lodgepole pine from the same sawmills. It therefore appears that incised subalpine fir is eminently the more suitable of the two species for pressure treatment (Morris 1990). Although not part of the above comparison interior spruce was reported to be a refractory (i.e., difficult to treat) species (Isenberg 1980).

TABLE 6. Principal properties and end uses of S–P–F (Isenberg 1980)

Property	Subalpine fir	Engelmann spruce	Lodgepole pine
Relative density	0.33	0.38	0.40
Heating value Million BTU/cord (O.D.)	14.484	16.235	18.655
Texture	Medium to coarse	Medium to fine	Medium fine
Resin canals	No	Yes	Yes
Grain	Straight and even	Straight and even	Straight and uneven
Workability	Easy	Easy	Easy
Stability when dried	Stable	Stable	Stable
Beam strength[a]	Low	Moderately low	Moderately strong
Stiffness[a]	Moderately stiff	Low stiffness	Moderately stiff
Post strength[a]	Moderately strong	Moderately low	Moderately strong
Nail withdrawal resistance	Moderately low	Good	Good
Glueability	Easy	Easy	Easy
Decay resistance	Low	Low	Low
Paint holding	Low	–	–
Accepts preservatives (treatability)[b]	Difficult[b]	Difficult	Heartwood – difficult Sapwood – easy
Uses of wood	Lumber, plywood, pulp, boxes, crates	Lumber, plywood, excellent pulp wood, mine timbers, poles, ties, fuel	Lumber, plywood, pulp, fence posts, mine timbers, telephone poles, railway ties, fuel, siding, panelling, cabinetry, flooring, composite-boards

[a] No reference to strength test method.
[b] Work at Forintek suggests that incised subalpine fir is more treatable than lodgepole pine (Morris 1990).

5 FUTURE POTENTIAL

In 1987, the Canadian Council of Forest Ministers concluded that Canada will continue to be a major producer of newsprint, market pulp, and softwood lumber. The competition for commodity forest products has so intensified the cost-competitiveness of mills that there is now a recognized need for value-added products.

Value-added products potentially obtainable from subalpine fir are: pressure treated wood, Laminated Veneer Lumber (using densified veneer), wood-cement composite boards, and liquid fuels.

Timber supply data indicate that British Columbia has little fibre left for industrial growth, except in modest hardwood tracts in the Interior. The Annual Allowable Cut data in the province is currently oriented toward lumber-quality timber, and does not include reasonable quantities of pulp-compatible softwood timber in either the coastal or interior regions (Woodbridge, Reed and Associates 1988). Thus, while there is little surplus of fibre for lumber, there is room for growth in the pulp and paper sector (Woodbridge, Reed and Associates 1988; Reed 1989).

In 1987, Canada's pulp and paper sector accounted for an estimated 70% of the total value of forest products, compared with 30% for wood products (Woodbridge, Reed and Associates 1988.) In British Columbia, the ratio is about 47 and 53%, respectively (COFI 1988). Projections indicate a more robust growth for the pulp and paper sector than for the softwood lumber sector (Woodbridge, Reed and Associates 1988; Widman Management Limited 1989).

In the recent past, kraft pulps were a profitable commodity on the international market. The future, however, seems to favour mechanical or ground-wood pulps, and new technology has made this process more energy efficient and environmentally sound. The long-term outlook for the pulp and paper sector is excellent, and subalpine fir is a reasonable wood for both kraft and mechanical pulping.

At the same time, wood products are forecast to continue as the dominant home building material in the USA and Canada. New housing is expected to remain the major market for wood products over the next 50 years (Marcin 1987). Higher energy costs are also likely to prevent non-wood materials from displacing lumber (Youngs 1982; Marcin 1987). All of these factors bode well for the future demand for subalpine fir.

6 INFORMATION NEEDS ON WOOD QUALITY

To date, little work has been carried out to characterize the basic wood properties of subalpine fir. Relative wood density, the most critical of the wood properties discussed, should be studied in relation to differing growth and site conditions. For example, relative wood density of subalpine fir should be examined with respect to: open-grown versus stand-grown trees; decadent old-growth versus vigorous second-growth trees; and fast growing (wide annual rings) versus slow growing (narrow rings) trees.

The impact of site conditions (such as elevation, aspect, and moisture regime) on wood quality also merits further study, as does the effect of management regimes on wood and fibre properties. Any species-to-species comparisons must ensure that trees are sampled at the same location.

Finally, all potential uses of the wood should be considered, not just sawlogs and solid wood products.

7 CONCLUSIONS

The poor reputation of subalpine fir in the forestry, logging, and sawmilling sectors is largely due to the use of decadent wood from overmature forests.

The main problems with subalpine fir are: a high incidence of decay in trees, which reduces lumber (chip) recovery; difficulties with lumber drying, which results in lumber degrade; and inherently low wood density, which leads to weak dimensional lumber and plywood, and low kraft pulp yields.

However, the information presented in this report clearly shows that in the future, second-growth subalpine fir should lose its poor reputation. With the liquidation of the overmature forest inventory and an expected rotation not to exceed 140 years, the problems associated with decay in the species should be greatly reduced. The lumber drying problem can be handled by moisture sorting technologies, now in place. Furthermore, even though subalpine fir has a lower relative wood density than its associates, Engelmann spruce and lodgepole pine, its properties are either identical or not significantly different in 11 out of 15 properties examined.

Despite these findings, among the many experts who grow, log, mill, dry, grade, chip, pulp, promote, market, and use subalpine fir, not a single one in our review expressed a preference for the species.

In twenty years from now, little is expected to change with the subalpine fir solid wood products market, unless the species is "discovered" like lodgepole pine was in the recent past.

Although the market outlook is highly favourable for all forest products, the prospects for growth are expected to shift away from solid wood products. Softwood lumber manufacturing expansion will reach its limit within the next decade, as sawlog-quality timber inventories are exhausted. The surplus of pulp-quality timber will likely lead to greater expansion in the pulp and paper sector. Major opportunities are expected for mechanical pulp in the world marketplace in the next 20 years because of British Columbia's S–P–F resource base and cheap energy. Subalpine fir is one species that will find a greater utility in this expansion.

8 REFERENCES

Bier, J.E., P.J. Salisbury, and R.A. Waldie. 1948. Decay in fir, *Abies lasiocarpa* and *A. amabilis*, in the upper Fraser region of British Columbia. Dom. Can. Dep. Agric. Tech. Bull. 66. 28 p.

B.C. Forest Service. 1976. Metric diameter class, decay, waste and breakage factors for all Forest Inventory Zones. For. Inventory Division, Victoria, B.C.

COFI. 1988. British Columbia forest industry statistical tables. April 1988. Vancouver, B.C. 8 p.

CSA (Canadian Standards Association). 1984. Engineering design in wood (working stress design) prepared by Canadian Standards Association. Rexdale, Ont. CAN3-086-M84

Dobie, J. 1970. Trends in forest resource use and forest products manufacturing in British Columbia. West. For. Prod. Lab., Vancouver, B.C. VP-X-75. 35 p.

Doerksen, A.H. and R.G. Mitchell. 1965. Effects of the balsam woolly aphid upon wood anatomy of some western firs. For. Sci. 11(2):181–188.

Eis, S. and D. Craigdallie. 1983. Regeneration and growth of white spruce and alpine fir in the interior of British Columbia. Can. J. For. Res. 13:339–343.

Forster, S. 1987. Sclereid control at Canfor Prince George Mills. Preprint for CPPA Technical Section Conf. at Whistler, B.C., May 1987. 6 p.

Fowells, H.A. 1965. Silvics of forest trees of the United States. U.S. Dep. of Agric., Washington, D.C. Agric. Handb. No. 271.

Haygreen, J.G. and J.L. Bowyer. 1989. Forest products and wood science: an introduction. Iowa State Univ. Press, Ames, Iowa. 500 p.

Herring, L.J. 1977. Studies of advance subalpine fir in the Kamloops forest district. Res. Note 80. B.C. Min. of For., ISSN 0384-2002. 23 p.

Hosie, R.C. 1969. Native trees of Canada. 7th ed. Queen's Printer for Canada, Ottawa, Ont. 380 p.

Hyttinen, A., E.L. Keller, and E.R. Schafer. 1958. Experiments on the groundwood and sulfite pulping of subalpine fir. U.S. For. Serv., For. Prod. Lab., Madison, Wis. Pub. No. 2122. 14 p.

Isenberg, I.H. 1980. Pulpwoods of the United States and Canada. Vol. I: Conifers. Revised by M.L. Harder and L. Louden. 3rd ed. The Institute of Paper Chemistry, Appleton, Wis. 219 p.

Jessome, A.P. 1977. Strength and related properties of woods grown in Canada. East. For. Prod. Lab. For. Techn. Rep. 21. 37 p.

Logan, J.D. and F.K. Bechtel. 1983. Steps to machine stress rated lumber production. Metriguard Inc. Feb. 17, 1983. 55 p.

Mackay, J.F.G. and L.C. Oliveira. 1989. Kiln operator's handbook for Western Canada. Forintek Canada Corp., Vancouver, B.C. Special Pub. No. SP-31. 53 p.

Madsen, B. and R.G. Sexsmith. 1983. Recent developments in timber engineering. Can. J. Civil Engineering 10:722–739.

Marcin, T.C. 1987. The outlook for the use of wood products in new housing in the 21st century. For. Prod. J. 37:(7/8):55–61.

Monchak, D.K. 1982. Factors affecting the growth performance and management of subalpine fir advance regeneration in the Kamloops Forest Region. Project report prepared for the B.C. Min. For., Silv., Kamloops, B.C. 131 p.

Morris, P.I. 1990. Suitability of alpine fir for pressure treatment. Forintek Canada Corp., Vancouver, B.C. Paper prepared for American Wood Preservers Assoc. June 1990. 6 p.

National Lumber Grades Authority. 1987. Standard grading rules for Canadian lumber. Vancouver, B.C. 207 p.

Nielson, R.W., J. Dobie, and D.M. Wright. 1985. Conversion factors for the forest products industry in Western Canada. Forintek Canada Corp., Vancouver, B.C. Special Pub. No. SP-24R.92P.

Reed, F.L.C. 1989. North American timber supplies: are we running out of wood? Prepared for First Bi-Annual Paper & Forest Products Investment Conf. Sponsored by Scotia McLeod, Toronto, Ont. 31 p.

Salamon, M. 1975. Kiln drying schedules for alpine fir. Can. For. Ind. (Sept. issue).

Simmonds, F.A. 1965. Engelmann spruce, subalpine fir, and lodgepole pine mixtures for bleached groundwood, kraft, and sulphite viscose-grade pulp. U.S. For. Serv., Madison, Wis. Res. Paper FPL-38. 8 p.

Smith, R.B. and H.M. Craig. 1968. Decay in advanced alpine fir regeneration in the Prince George district of British Columbia. For. Chron. 44(3):37–44.

_____. 1970. Decay in advanced alpine fir regeneration in the Kamloops district of British Columbia. For. Chron. 46(3):217–220.

Troughton, G.E. and M.R. Clarke. 1987. Development of a new method to measure moisture content in unseasoned veneer and lumber. For. Prod. J. 37(1):13–19.

Widman Management Limited. 1989. Markets 89 – 93. The outlook for North American forest products. Vancouver, B.C. Jan. 1989. 222 p.

Woodbridge, Reed and Associates. 1988. Canada's forest industry the next 20 years: prospects and priorities. Vancouver, B.C. Vol. I. 223 p.

Youngs, R.L. 1982. Every age, the age of wood. Interdisciplinary Science Reviews 7(3):211–219.